ENERGY, MINES AND RESOURCES

A MARKET STUDY TO EVALUATE THE DEMAND FOI DIRECT QUENCHED PLATE STEELS

JUNE, 1982

Price Waterhouse Associates

MANAGEMENT CONSULTANTS

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MICROMEDIA

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1.0 INTRODUCTION

For the past five years, CANMET has been investigating direct quenched low carbon, high strength low alloy (HSLA) steels. These steels obtain their properties through a combined thermo-mechanical process and a controlled cooling process which optimizes their strength/toughness properties. The direct quench process achieves very high cooling rates which further strengthens the steel through a transformation mechanism. This process was originally developed by British Steel but is also under investigation in Japan and France.

Direct quenching requires a modern in-line roller quench unit to achieve faster cooling rates than a traditional laminar spray system. Technically, this would allow steel producers to extend their capabilities in low carbon HSLA steels or produce current grades with a leaner composition. Steel mills could produce higher yield strengths in thick plates without unduly sacrificing notch toughness or weldability.

Direct quenched plate could also displace some traditional quenched and tempered alloy steel plates in applications requiring high strength with good weldability and toughness (e.g. line pipe, ship plate and structural plates). Direct quenched steels may have a significant cost advantage over quenched and tempered steels due to a cheaper production process and lower total alloy content.

CANMET has made its test and research results available to steel producers and users. However, Canadian steel producers are reluctant to invest in commercial development of direct quenched products without an evaluation of its demand potential. Therefore, CANMET engaged our firm to conduct a market study to evaluate the demand for direct quenched plate steels.

The emphasis of this study was to identify potential product and market applications and to assess demand trends and potential. Such information would be useful to Canadian steel producers, who must arrive at an investment decision, and useful to CANMET in directing the efforts of its HSLA steel research and development activity.

2.0 EXECUTIVE SUMMARY

In this section, we provide a brief overview of the major findings and market analysis discussed throughout this report.

The typical annual domestic consumption of plate less than 1.5 inches in thickness is approximately 1,560,000 tonnes. Of this demand, roughly 60% or 935,000 tonnes is under 50 ksi yield strength plate used extensively in structural non-tensile design applications. The other major market is 50 - 70 ksi plate which accounts for 37% of total demand or 575,000 tonnes per year. High strength line pipe and tube manufacturing accounts for approximately 75% of the total 50 - 70 ksi yield stength plate demand. The market for over 70 ksi plate is estimated at 50,000 tonnes per year or 3% of total consumption. In this small market, demand is largely for 100 ksi yield strength structural plate and abrasion resistant plate.

In structural plate, ship plate and line pipe applications, users believe that a trend toward higher strength steel plate exists and will continue in the future. However, the trend is expected to be slow and occur in small strength increments (e.g. 5 - 10 ksi). Additionally, most users indicated a need for improved quality and/or toughness properties in conjunction with higher strength plate development.

Past demand for higher strength plate first appeared in applications where tensile strength was a major design criteria and thus, higher strength plate had a significant impact on construction and/or in-service economics (e.g. pipe lines, trailers, off-highway equipment, etc.) Conversely, user driven demand for higher strength plate has not occurred in applications where tensile strength is of less importance (e.g. welded structures, tanks, ships, etc.) In these applications, the material savings from the use of higher strength thinner plate is unclear as these savings could be offset by higher plate costs, increased stiffener requirements and higher fabrication costs. These users claim unsatisfactory economic experience with higher strength plate and are thus reluctant to use these materials. Therefore, lower cost

plate in current and marginally higher strength grades would be attractive in this market.

Line pipe and ship plate requirements for Arctic and off-shore oil and gas development represent a future application of higher strength and/or tougher plate.

Higher strength and tougher line pipe could allow the use of higher operating pressures which would improve the cost of service economics. A preliminary study has shown that use of grade 100 offers the potential for savings in the order of 10 - 20% over grade 70 economics. However, while the economics are attractive, the steel industry, users and regulatory groups are conservative in their design and development approach to higher strength pipe. Thus, it is likely that future demand will be for marginally higher strength line pipe grades and driven by favourable user economics. We estimate that resource project line pipe demand to 1995 could total up to 3,300,000 tonnes.

The future demand for ship plate for Arctic vessels and off-shore structures is expected to be largely 50 - 70 ksi in yield strength. Aside from weight reduction benefits in semi-submersible platforms, higher strength plates are not seen to offer significant economic advantages over lower strength thicker plate as flexural design conditions exist. The major trend in this application is toward lower transition temperature, tougher thick plate grades. As both toughness and strength are increased by grain refinement, it is likely that higher strength ship plate will be developed. However, such development may be fostered by the need for lower temperature toughness rather than the economic advantage or need for higher strength ship plate. With respect to resource project demand to 1995, we estimate that total 50 - 70 ksi ship plate requirements could approach 1,800,000 tonnes.

It should be noted that line pipe and ship plate demand figures are based on competing oil and gas transportation systems. Therefore, these figures should not be totalled as some double counting would likely result.

The market for 100 ksi structural plate and abrasion resistant plate is small in comparision to other plate markets. With typical consumption at 50,000 tonnes per year, the economic impact to steel producers from substitute or new product development is somewhat limited. While direct quenched plate would be less costly than traditional quenched and tempered plate, quality and uniformity of properties are also important to users. Therefore, it is likely that establishing new products and/or processing technology would require an extensive end user marketing effort. Given the limited market potential and the marketing effort necessary, steel producers indicated that economic benefits were insufficient to justify high capital investment.

Canadian steel producers have shown interest in on-line accelerated cooling (OLAC), but at this time, there is little interest in direct quenching. Canadian plate mill layouts would likely prohibit economic installation of the in-line roller quench unit. Additionally, producers do not see a significant market for the extended thickness and yield strength capabilities of the direct quench system at this time. Producers believe that OLAC capabilities are more consistent with the future strength requirements in the high tonnage markets and applications. With high tonnage demand, OLAC investment could be justified on alloy reduction and processing cost saving.

High capacity utilization is essential to the steel industry's profit performance. It has traditionally avoided over building or excessive capacity in relation to domestic consumption. Canadian steel mills, therefore, have avoided dependence upon export markets and are unlikely to consider export potential as justification for capital investment in direct quench equipment. Therefore, we have not attempted to quantify export demand for high strength, low alloy plate steels using direct quench processing technology.

3.0 SCOPE AND APPROACH

Our study terms of reference required an analysis of demand for 0.5-1.5 inch thick plate of 50 - 100 ksi yield strength with good toughness and weldability. Specific applications to be studied included line pipe, ship plate, structural and abrasion resistant plate. In conducting the study, we found it necessary to marginally expand the scope of the investigation to encompass other potential applications. As a result we considered 0.25 - 1.5 inch thick plate with yield strengths ranging from about 38 - 100 ksi.

Our study was to examine the defined product market applications. In each application or market, we attempted to identify steel plate products or grades that could utilize and benefit from the cost and/or property advantages of "tranformation strengthening" technologies such as direct quenching. Therefore, in each market and application, our approach was to:

- interview users to assess needs, trends and market potential from the demand side;
- interview steel producers to assess the merits of plate mill processing technologies, subsequent heat treatment requirements, and market potential from the supply side;
- define further key products, markets and opportunities;
- review various end user, resource industry user, and steel industry documents to identify product and market uncertainties that could impact on demand; and
- prepare estimates of product and market demand to the year 1995.

In conducting this study, the number and type of organizations we contacted are summarized as follows:

- 5 steel producers;
- 6 pipe line companies/project groups;
- 4 petroleum companies;
- 4 firms designing and developing Arctic grade steels and structures;
- 9 steel service centres; and
- 15 steel fabricators and ship builders.

4.0 CANADIAN PLATE MARKET

4.1 Product Applications and Markets

The market for tough, weldable plate steels encompasses a range of product applications. Within each application, market demand can be examined as a function of yield strength. Therefore, we segmented the market into product applications and further segmented these by yield strength ranges.

The key product applications we identified are:

- line pipe;
- plate for ships and offshore structures; and;
- structural plate including:
  - high strength plate; and
  - abrasion resistant plate.

Similarly, yield strength subsegments were established as:

- less than 50 ksi;
- 50 ksi to 70 ksi; and
- greater than 70 ksi.

4.2 Current Annual Plate Consumption

From information we obtained from steel producers and other statistical records, we estimated current annual plate consumption in total and by product/yield strength market. These total consumption estimates and application breakdowns are shown in Exhibit 1. Our estimates are not based on a specific year. Instead, these estimates reflect reasonable market expectations in a typical, but not exceptional, year.

This exhibit shows that the two major plate market segments are "under 50 ksi general structural plate" at about 60% and "50 - 70 ksi plate for pipes and tubes" at about 30%.

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Exhibit 1

TYPICAL ANNUAL CANADIAN PLATE DEMAND
(IN METRIC TONNES)

PLATE CATEGORY	YIELD STRENGTH SEGMENTS			TOTAL CANADIAN CONSUMPTION
	UNDER 50 KSI	50 – 70 KSI	OVER 70 KSI	
GENERAL STRUCTURAL PLATE	862,000	118,000	20,000	1,000,000
PLATES FOR MFG OF PIPES AND TUBES	95,000	405,000	NIL	500,000
SHIPS AND OFF SHORE STRUCTURES	18,000	12,000	NIL	30,000
ABRASION RESISTANCE	NIL	NIL	25,000	25,000
DOMESTIC SHIPMENTS	975,000	535,000	45,000	1,555,000
IMPORTED PLATE	125,000	65,000	5,000	195,000
APPARENT CONSUMPTION	1,100,000	600,000	50,000	1,750,000
(LESS PLATE OVER 1.5" THICK)	(165,000)	(25,000)	(NIL)	(190,000)
ANNUAL PLATE CONSUMPTION LESS THAN 1.5" THICK	935,000	575,000	50,000	1,560,000
PER CENT OF PLATE LESS THAN 1.5" THICK	60%	37%	3%	100%

A very high percentage of structural and ship plate applications do not require high tensile strength. Engineers are concerned with plate stiffness and flexural design. Additionally, plate cost, weldability and formability affect construction economics. Thus, 90% of structural plate demand is under 50 ksi yield strength. Consistent with this information, we note that a very high percentage of the structural and ship plate demand in the 50 - 70 ksi segment is only marginally over 50 ksi in yield strength.

Applications for over 70 ksi structural plate usually require very high tensile strength (for reducing weight) or high abrasion resistance (for prolonging service life). As these requirements are major design criteria and as both properties are achieved by a quench and temper heat treatment, a very high percentage of this demand exceeds 100 ksi yield strength.

Exhibit I shows that more than 80% of the demand for plate used for pipes and tubes is in the 50 - 70 ksi yield strength range. This strength range is the current practical controlled rolling limit of most Canadian steel producers. A high percentage of this tonnage could shift to the over 70 ksi market with the continuing trend towards higher pressure gas pipelines requiring higher strength line pipe (e.g. grade 80). Demand also exists for less than 50 ksi line pipe. This grade of pipe is used in small diameter designs where minimum wall thickness requirements negate the advantage of higher strength pipe.

Our estimates put annual plate consumption (less than 1.5 inches thick) at about 1,560,000 tonnes. Of this demand, roughly 60% is under 50 ksi yield strength and used in structural (non-tensile design) applications. The other major market is 50 - 70 ksi plate for pipe and tubes which totals 575,000 tonnes and accounts for 37% of total consumption. With respect to high strength structural and abrasion resistant plate, we estimate current annual demand at about 50,000 tonnes or 3% of the total plate consumption.

5.0 LINE PIPE

Line pipe is currently available in grades up to 70 ksi yield strength. Strength and toughness properties are achieved by controlled rolling, micro-alloying, and steelmaking practice. Grade 70 approaches the current practical limit of this technology for many steel mills.

There are two possible applications of higher strength line pipe, say, grades 80 to 100:

- to raise design operating pressures to increase the volume flow rate of a given line, and thus, improve the cost of service economics; and

- to reduce wall thickness requirements of a given line and thus save line pipe material costs.

The first application was considered the most appropriate use of higher strength materials and the one with the greater economic impact. Pipe working stress levels are a function of operating pressure and pipe diameter. Construction and design codes limit working stress as a percentage of the material's specified minimum yield strength. The higher the yield strength, the higher the working stress design limit.

The second alternative, while feasible, was considered less attractive to design engineers. Reducing wall thickness can cause welding alignment difficulties. Furthermore, thin walled pipe is more susceptible to handling damage and in-service buckling failure as a result of heaving or spanning. Engineers felt that these conditions dictated a minimum wall thickness in the range of 0.25 inches. Thus, the modest one-time savings in materials, from use of a thinner wall pipe, did not create much interest as fabrication and longevity risks were considered to be increased.

5.1 User Trends

We examined trends in both oil and gas transmission systems. We will deal with these trends under these system headings.

Gas Transmission Systems

To improve cost of service economics, gas transmission companies have been increasing design operating pressures. It appears that this trend will continue throughout the 80's. In the 70's, design engineers worked with operating pressures in the range of 900 - 1,100 psi. Presently, lines are being designed to operate at up to 1,440 psi using grade 70 material. Pipelines of the more distant future, such as the Polar Gas project, contemplate operating pressures of greater than 1,600 psi. These later pipelines can be made from heavier wall grade 70 pipe. However, higher strength grades (e.g. grade 80 to grade 100) may be able to improve cost of service economics by allowing the use of higher pressure or thinner wall pipe.

The second notable trend has been in the area of improved weldability. Tighter specifications on chemistry and carbon equivalent levels, along with developments in welding procedures and consumables, have resulted in acceptable levels of weldability for all grades of material. Weldability must be demonstrated for new materials. However, the industry is confident that procedures and consumables can be developed to weld higher strength materials.

The major trend and concern of engineers at the present time relates to notch toughness. Toughness properties were first specified in the early 70's. At the present time, much attention is focussed on defining toughness requirements for fracture control of grades 70 and higher.

In pipeline design, it is necessary to consider both fracture initiation and fracture propagation control. Operating experience at pressures in the range of 1,000 psi has shown that ruptures are extremely rare. This is largely due to use of line pipe with adequate toughness to prevent crack initiation. For

example, tests of 42" pipe supplied to the Alaska Highway project show that suppliers greatly exceeded the specified minimum Charpy energy value of 54 J at -5°C.

The trend toward higher operating pressures using higher strength pipe may require improved toughness properties. Industry engineers, using the Battelle/AGA model to predict fracture toughness, tentatively estimate that a 42" O.D. grade 100 line, operating at a minimum of 1,500 psi, would require minimum Charpy energy values of roughly 80 J (crack initiation) and 160 J (crack arrest). This example assumes all heat average values at a design temperature of -5°C.* The estimated crack initiation toughness value is just within the limit of current HSLA steelmaking and processing technology. However, the required crack arrest energy represents a very stiff toughness specification for many producers of as-rolled HSLA steels. Therefore, the industry expects that future high strength, high pressure lines will require a different approach to fracture control, such as independent crack arrestor devices.

From our field interviews with these users, we have drawn the following conclusions with respect to industry practice and higher strength materials:

- tightening of design codes and specifications has made the industry somewhat conservative towards new materials. In the case of new materials and designs, the industry must clearly demonstrate the engineering technology and safety of such designs to regulatory groups;

- grade 70 line pipe presently represents a relatively new material to the industry. The industry is only now gaining experience in design, construction and in-service operation for complete lines and on a large scale basis;

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* Based on discussions with Ron Jamieson and Jim Justice of Transcanada Pipelines Limited.

- the industry has not done extensive work to examine the feasibility of higher strength materials such as grade 100. While some initial economic studies have been developed, extensive effort has not been devoted to establishing material properties and identifying other areas of technology development. However, the industry cited the following areas of concern that must be addressed when development proceeds:

  - required toughness specifications and appropriate methods of fracture control;

  - weldability and development of suitable techniques and consumables;

  - development of suitable strength flanges and fittings;

  - examination of fatigue resistance;

  - examination of corrosion resistance;

  - examination of sour fluid capability;

  - development of field construction and forming techniques; and

  - economic value of such materials.

A very preliminary analysis of a high pressure grade 100 vs. a low pressure grade 70 pipeline suggests that use of this higher strength material could reduce total cost of service by 10% to 20% depending on pipe diameter.* The two key assumptions in this preliminary analysis are:

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* Based on a paper by E. Shelton, A.B. Rothwell, and R.I. Coote, Nova, An Alberta Corporation, "Steel Requirements for Current and Future Canadian Gas Pipeline Systems".

HYPOTHETICAL VALUE ANALYSIS
GRADE-70 VS GRADE-100 PIPE LINES

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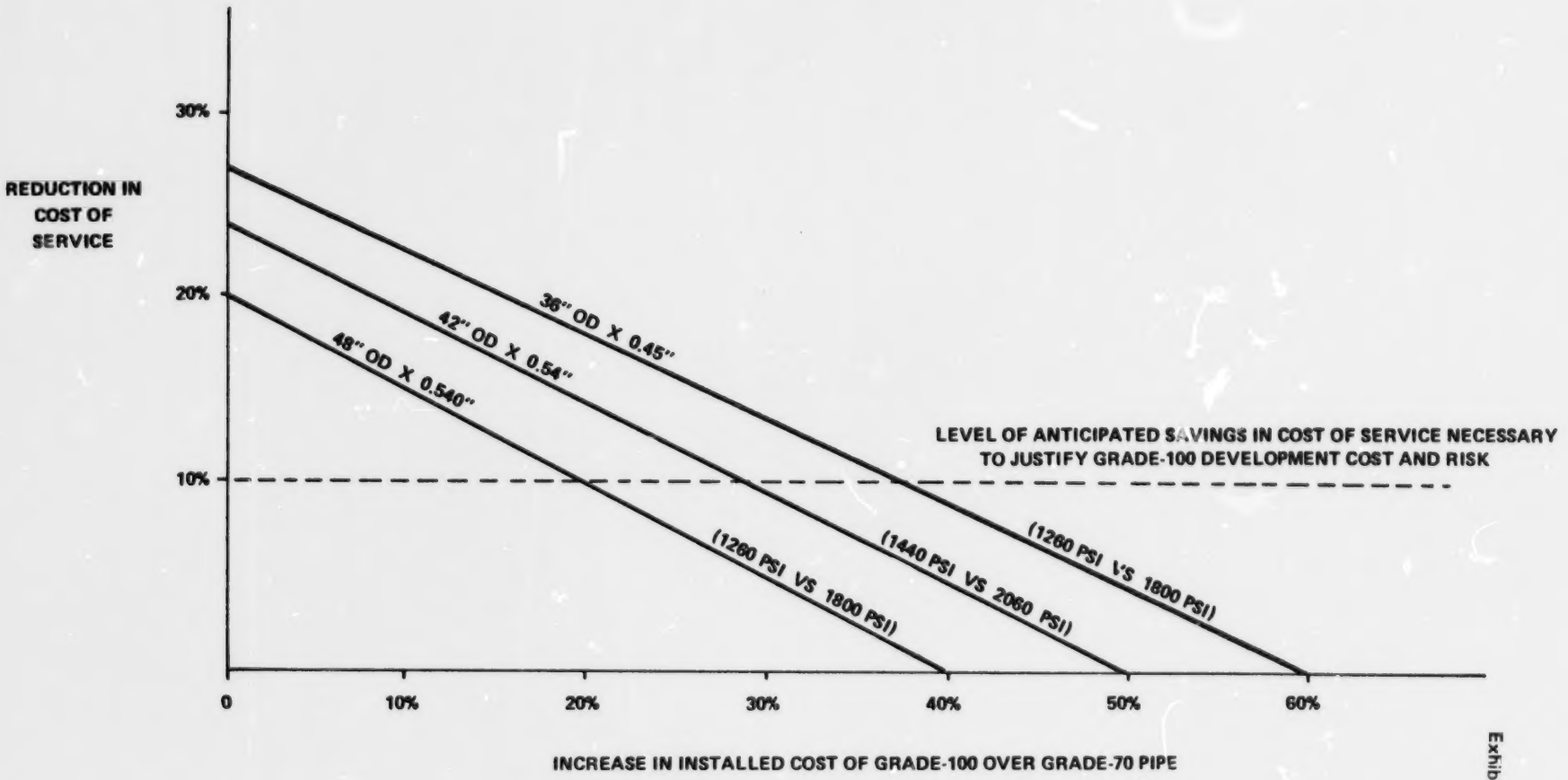

Exhibit 2

- the installed cost of the line pipe is 2.5 times the purchase cost of grade 70 or grade 100 pipe; and

- grade 100 line pipe is only 20% more costly than grade 70 line pipe for a given pipe diameter and wall thickness.

The net effect and intent of these two assumptions is that the assumed total installed cost of grade 100 pipe be 20% greater than grade 70 pipe. The analysis suggests that there is still sufficient savings (i.e. at least 10%) in the cost of service to justify the use of grade 100. Drawing on the information presented in the Nova report, we constructed Exhibit 2 to illustrate the relationship between: reduction in cost of service; increase in installed pipe cost; and pipe dimensions. The figures shown in the exhibit in brackets are the assumed internal pressures for the grade 70 line vs. the grade 100 line.

From a pipe producer's viewpoint, a critical question is what price premium can the user afford to pay for grade 100 vs. grade 70 pipe and whether this adequately covers the increased cost of production. The Nova analysis doesn't address this point. The analysis assumes that total installed cost will be about 2.5 times the purchase cost of the pipe for both the grade 70 and grade 100 pipe lines. It then uses this higher installed cost to calculate the anticipated reduction in cost of service. However, the two principal components of total installed cost are: purchased price of the pipe; and installation costs such as ditch preparation, field welding, etc. For example, if the installation cost for grade 100 is only 10% greater than for grade 70, then the price premium for the purchased pipe could be as much as 35%. This combination of cost increases still results in an overall increase in total installed cost of 20%.

Firm conclusions about the economic incentive available to producers of grade 100 should not be drawn on the basis of this preliminary economic analysis and

our interpretation. Rather, we wish to further encourage this type of economic and value analysis so that the incentive to develop higher strength line pipe can be clearly identified.

Oil Transmission Companies

Oil pipeline design trends are similar to gas pipeline design trends. However, trends in oil pipe line design have progressed at a slower, more conservative rate.

The mechanics of oil transmission and fluid properties dictate a more conservative design approach. Oil is incompressible and sometimes, a sour fluid. Designs are concerned with steel ductility and fatigue properties to prevent failure from high pressure surges that result from changes in transmission volume. Additionally, the steel's resistance to hydrogen embrittlement is an important concern. These concerns make thick wall designs and medium yield strength materials (e.g. grade 52) favourable.

Trends towards better weldability and improved sour fluid capability are clear. A trend toward higher operating pressure exists as the economics of higher pressure lines are attractive. However, the trend towards higher pressure has not developed to the same extent as in the gas transmission industry. The proposed Norman Wells oil pipeline is designed to operate at 1,000 psi. Its specifications call for the following type of pipe: 12" O.D.; 0.25" wall thickness; and grade 52.

In the past, toughness has not been a major design criterion. As crude temperatures are maintained at approximately +5°C, low temperature toughness has not been required. As a result, most existing transmission lines are made of category I material (i.e. no demonstrated low temperature toughness). The industry feels that toughness specification will be necessary for future oil pipelines. CSA code Z183 has established requirements of 27 J at the design temperature for low temperature service.

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Exhibit 3

ESTIMATED PROJECT DEMAND FOR LINE PIPE

1983 – 1995

PROJECTS TO 1995	TONNES OF LINE PIPE	
	GR.-52 – GR.-65	GR.-70 AND UP
1. LNG GAS EXPORT LINE		127,000
2. VANCOUVER ISLAND GAS LINE	16,000	26,000
3. ALASKA HIGHWAY GAS PIPELINE (56" LINE)		1,180,000
4. DEMPSTER GAS PIPELINE		282,000
5. ARCTIC PILOT PROJECT LINE		15,000
6. POLAR GAS LINE *		1,705,000
7. NORMAN WELLS OIL LINE	43,000	
8. BEAUFORT SEA OIL LINE **	928,000	
9. OFF SHORE SABLE ISLAND GAS DEVELOPMENT		35,000
TOTALS	987,000	3,370,000

* POLAR GAS LINE COMPETES WITH A LNG TANKER TRANSPORT OPTION FOR BOTH ARCTIC ISLAND AND BEAUFORT SEA GAS FIELDS.

** BEAUFORT SEA OIL PIPELINE ALSO COMPETES WITH A TANKER TRANSPORT OPTION.

The availability of grade 100 line pipe could allow use of pressures in the range of 1,500 psi. However, use of these pressures is unlikely to occur in the short or medium term. Oil pipeline designers appear to be more conservative than their gas pipeline counterparts. They regard the environmental damage resulting from an oil line failure to be more severe than that from a gas pipeline failure.

The industry has done little exploratory work on higher strength materials as they do not feel that they can safely and economically utilize the highest strength grades that are currently available. The list of material concerns that engineers identified were consistent with those established by gas pipeline engineers.

5.2 Line Pipe Market Opportunities

The demand for line pipe, to the year 1995, will be strongly influenced by the schedule of frontier resource development projects.

In Exhibit 3 we have listed the expected pipe line projects for this period, assuming all development will utilize a pipe line transportation system. Current specifications were used to classify tonnage by grades. The results show that project demand for line pipe in grades 52 to 65 could approach 1,000,000 tonnes. Similarly, the estimated demand for grades 70 and up approaches 3,300,000 tonnes.

Aside from market, economic, political and technical constraints related to these projects, demand will be constrained by two additional factors:

- the selected transportation system for frontier reserves; and
- the development of fracture control and welding techniques, fittings and valves in conjunction with line pipe steel development.

From a user standpoint, higher strength materials (i.e. greater than 70 ksi) appear economically justifiable. However, the industry is very conservative in its approach to use of new materials. Sufficient lead time is required to demonstrate:

- uniformity of properties from commercial scale processes;
- fracture control at higher design pressures;
- weldability;
- resistance to hydrogen embrittlement;
- fabrication and construction techniques; and
- in-service reliability.

As current grade 70 grades are still considered new materials, the industry needs to gain experience at this strength level. Thus, there is little motivation to request significantly higher strength, high toughness line pipe at this time. However, we understand that a Japanese mill is supplying grade 80 type line pipe to the USSR.

In the short to medium term, the trend appears to be towards improvement in current grades of line pipe steels at a lower total production cost. If existing grades could be produced with current levels of weldability and toughness on a more economic basis, these materials would have a significant cost advantage.

New steel processing technology may be required to optimize product cost and properties in existing grades. The Japanese steel industry appears to be actively exploring new processing technology (e.g. on-line accelerated cooling) to improve its cost advantage in existing grades.

5.3 View of Canadian Steel Producers

Steel producers are not able to predict the cost of producing grade 100 pipe at this time. It is not yet clear that the required steel and pipemaking

technology could achieve the required properties for an acceptable cost increase. As such, the economics of developing grade 100 are uncertain and possibly unattractive.

Canadian steel mills believe that the market for grade 70 line pipe will continue through the 80's. Consistent with the industry view, steel producers consider grade 70 to be a relatively new material. Also, they see the trend to higher strength line pipe at a slow rate with small increments in strength being developed, demonstrated, tested and finally, specified for new line construction.

Steel producers seem to agree that grade 70 is close to the limits of controlled rolled technology. As such, they are interested in investigating new technologies, such as on-line accelerated cooling or direct quenching. While such technologies may allow them to develop new products, they question justification of development capital based on the future demand for higher strength pipe products. Therefore, the steel producers will probably initially consider such technologies as a method for reducing the production cost of current line pipe grades.

Given uncertain energy market demand and economics of new Arctic transmission lines, pipe producers are justifiably reticent about developing new products. The risks are certainly high if these are the only likely applications for higher strength pipe. Furthermore, the pipe producers feel somewhat insulated from the threat of new imported products due to traditional "buy Canadian" practices and regulatory approval processes. It appears unlikely that a new pipeline would be approved at an early date if the material specification exceeded the capabilities of domestic steel and pipe producers. The combination of these factors is likely to inhibit the response time of the domestic industry to a developing market for higher strength line pipe.

6.0 PLATE FOR SHIPS AND OFFSHORE STRUCTURES

The market for ship plate, including offshore structures, is expected to increase significantly in the coming years as exploration of offshore and frontier oil and gas reserves continues. Large tonnages of ship plate will be required to construct Arctic class vessels and offshore drilling and production platforms.

Demand for these steels will be related to the rate of development of these reserves. The rate of development will depend on demand for these reserves, technology development and the economics of such undertakings.

Industry opinion appears to hold that frontier Arctic reserves are still very much in the early stages of development. While significant discoveries have been made, reserve potential and production rates have yet to be established. At this point, the industry is still uncertain about the potential of Arctic reserves and as such, exploratory drilling will continue for some time.

With respect to production and transportation of Arctic reserves, the industry is divided between pipeline and ice-breaking tanker options. While some companies profess commitment to a particular transportation form, others remain undecided at this time. The selected transportation system will have a significant impact on the demand for ship plate.

It appears that transportation by large diameter pipe line would be the most efficient method of transporting large volumes of oil and gas from the Arctic. However, Arctic class vessels capable of year round service would still be necessary to extend the exploration season and to permit servicing of production facilities. As such, it appears that Arctic marine technology must be developed regardless of the final transportation route. State-of-the-art engineering is necessary to deal with severe Arctic conditions. Vessels of this classification will be the first of their kind.

Offshore platforms capable of operation in ice infested regions will be necessary for development of both Arctic and East Coast reserves. Conventional offshore systems are unsuitable for use in other than thin ice conditions. Extensive engineering effort has been spent on the development of Arctic offshore platforms. Some of the systems proposed include:

- ice strengthened semi-submersibles;
- gravity cone structures; and
- caisson based structures.

Most of the above systems are expected to have fairly conventional hull designs comprising of a thick plate outer shell with skin stiffeners and bulkheads.

Ice strengthened semi-submersibles are an application where the performance benefits of higher strength thinner plate could be realized. It is desirable to minimize the weight of these floating structures. However, there is no clear trend to higher strength, thinner plate specifications at this time.

Gravity cone and caisson based structures are currently fabricated with grade EH36 ship plate. However, some designs favour the use of concrete for this application. The properties and cost of concrete make it an economical alternative in these applications.

While a large demand for Arctic ship plate is expected, the domestic steel industry may only experience demand in proportion to Canadian shipyard fabrication of these vessels and structures.

Total Canadian shipyard capacity is roughly 50,000 tonnes of steel per year. In terms of capability, Canadian shipbuilding yards do not have the ability to fabricate vessels more than 130 feet wide. Thus, the industry could only look at fabricating small to medium sized vessels. Vessels of this size would have steel hull weights of less than 20,000 tonnes.

If rapid development of the Arctic frontier occurs, it is evident that Canadian shipbuilding capability would be inadequate. However, if a slow rate of development transpires, Canadian yards could fabricate a significant number of small and medium size drilling and support vessels. A new shipyard would be necessary to fabricate large vessels such as crude carriers. However, significant uncertainties make the industry uncommitted to the development of this facility at the present time.

6.1 User Trends

Development of vessels and structures for the most severe Arctic conditions represents a trend into ill defined areas. Design criteria are not well understood. While there have been substantial advancements in understanding ice mechanics, designers face many unknowns in predicting ice forces. Thus, design of Arctic vessels and structures must be initially based on conservative criteria until better data and knowledge are available.

The trend in steel specification for both vessels and offshore structures is for improved low temperature toughness at current strength levels. Users are requesting that better toughness be achieved in all thicknesses at test temperatures as low as -75°C.

For EH36 grade plate less than 0.5 inches in thickness, specifications have called for a minimum Charpy energy value of 27 J at -60°C. For plates over 0.5 inches, an improved EH36 quality has been specified with a Charpy energy value of 34 J at -60°C. The Ni and Mo alloy content have been increased to 0.15% and 0.08% respectively to suppress the impact transition temperature.

Users believe that steel toughness, ductility, fatigue resistance and weldability are essential criteria. These steels must also exhibit good through thickness properties.

Users have not requested higher yield strength steels. The prospect of utilizing higher strength, thinner plate is not considered likely at this time. Engineers are concerned with designing for flexural failure in both ship and offshore structural applications. Thus, traditional thick ship plate steel such as grade EH36 is considered appropriate. Users feel that thinner, high strength plate, would require additional stiffeners and thus increase fabrication and welding costs. Additionally, thin plate may not provide a sufficient factor of safety against indented damage. An exception to this may be some applications in semi-submersibles structures where weight reduction is an advantage. However, designers appear to be reluctant to use steels with yield strength levels above current EH36 specifications (i.e. 51 ksi).

It appears that users are conservative in steel selection and may pay a premium price for improved quality EH36. The additional cost of material tends to be small as compared with the cost of labour for fabrication. Due to the amount of uncertainty in other areas of design, engineers appear reluctant to consider new, higher strength materials based on alternative steel processing technology.

6.2 Market Opportunities

At the present time, there appears to be no interest in higher strength plate for ship and offshore structural applications. Current levels of strength are considered to be adequate. Until evidence is gathered to alter the design criteria, higher strength material demand is unlikely. Therefore, the market for higher strength ship plate appears to be a long-term opportunity.

In the shorter to medium term, there appears to be an opportunity for better quality, more economical grades of ship plate. Improved low temperature properties, particularly in the through thickness direction, are required. In plates under 1.5" in thickness, new processing technology, such as on-line accelerated cooling, could be used to produce good quality low temperature plate while reducing processing time and alloy costs. In thicker plate, alloys savings could be realized to a somewhat lesser degree. Thicker plates

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Exhibit 4

ESTIMATED PROJECT DEMAND FOR SHIP PLATE

1983 – 1995

PROJECT/APPLICATIONS	NO. REQ'D	WEIGHT (TONNES)	PLATE REQUIREMENTS (1) < 1.5" THICK ≤ 50KSI (TONNES)	PLATE REQUIREMENTS (1) < 1.5" THICK > 50 KSI (TONNES)
1. EAST COAST ENERGY PROJECT				
. EXPLORATION SEMI-SUB	13	10,000	27,000	51,000
. PRODUCTION SEMI-SUB	4	25,000	21,000	39,000
. SUPPLY BOAT	31	1,000	7,000	12,000
TOTAL EAST COAST			55,000	102,000
2. ARCTIC ISLANDS LNG				
* . LNG CARRIERS	16	73,500	247,000	459,000
. STORAGE BARGE	18	12,500	47,000	88,000
. PROCESS BARGE	9	6,000	11,000	21,000
. ACCOMMODATION BARGE	5	3,000	3,000	6,000
TOTAL ARCTIC ISLANDS			308,000	574,000
3. BEAUFORT SEA OIL DEVELOPMENT				
. AMLX – 3 ICEBRAKER	12	3,000	8,000	14,000
. AMLX – 6 ICEBREAKER	3	6,000	4,000	7,000
. SUPPLY BOAT	22	1,700	8,000	15,000
. ACCOMMODATION BARGE	8	3,000	5,000	9,000
. DRILLING BARGE	17	15,000	54,000	100,000
* . ROUND DRILL SHIP	4	10,000	8,000	16,000
. DREDGE (CLASS 6)	6	20,000	25,000	47,000
* . PROCESS BARGE	5	20,000	21,000	39,000
* . STORAGE BARGE	5	70,000	74,000	137,000
* . ARCTIC CRUDE CARRIER	25	80,000	420,000	780,000
TOTAL BEAUFORT SEA			627,000	1,164,000
GRAND TOTAL			990,000	1,840,000

NOTES: (1) 80% OF HULL STEEL REQUIREMENTS ARE ASSUMED TO BE FOR PLATE. OF PLATE REQUIREMENTS, 65% ARE ASSUMED TO BE FOR HIGH STRENGTH PLATES (I.E. > 50 KSI). IN EACH STRENGTH RANGE, 75% OF PLATE REQUIREMENTS ARE ASSUMED TO BE LESS THAN 1.5 INCHES THICK.

* THESE VESSELS ARE GREATER THAN 130 FEET IN WIDTH AND CANNOT BE CONSTRUCTED IN EXISTING CANADIAN YARDS.

may still require further treatment. On balance, however, thick plate grades such as EH36, could be produced more economically by decreasing processing and alloy costs. Such steels would have acceptable toughness properties and improved weldability over current products (i.e. low carbon equivalent values).

Preliminary industry information on vessel steel requirements suggests that 80% of steel demand will be for plate. Of plate demand, 65% would be of grade EH36. It is expected that typical plate dimensions would be in the range of 40' in length and up to 10' in width. With respect to thickness, 35% of the plates would be less than 1.0" thick and 75% would be less than 1.5" in thickness.* Therefore, on the basis of vessel plate requirements, the demand for grade EH36 plate up to 1.5" thick would represent roughly 35-40% of total hull steel requirements.

Using this information, we examined industry project estimates of vessel and offshore structure requirements to the year 1995. We estimated hull plate steel requirements less than 1.5" thick. These estimates were grouped in yield strength ranges of less than 50 ksi and 50 - 70 ksi (Exhibit 4).

Our analysis shows steel requirments by project and strength range. In each case, the analysis assumes the use of a full marine transportaion system. This analysis yields estimates of roughly 1,000,000 tonnes of ship plate less than 50 ksi yield and 1,800,000 tonnes of plate greater than 50 ksi yield strengh. If requirements for vessels too wide to be fabricated in existing Canadian shipyards are excluded, the revised demand would be 467,000 tonnes (50 ksi) and 868,000 tones (50 - 70 ksi).

As previously discussed, the schedule of such projects is uncertain. Furthermore, selection of pipe line transportation systems would significantly reduce ship plate demand. The following additional constraints on demand exist:

- capacity and capability of Canadian shipyards;

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* Dome Petroleum Limited Report, "Forecasted Demand for Steel Associated with Beaufort Sea Development", October 15, 1981.

- strong competition from foreign ship builders;
- possible use of concrete for Arctic offshore platforms; and
- acceptance by users and regulatory groups of higher strength steels and associated steelmaking technology.

6.3 Views of Canadian Steel Producers

Canadian plate mills currently have the capability to produce grade EH36 and modified EH36 low-temperature steels. Modified EH36 achieves better impact toughness properties by modifying normal Ni and Mo EH36 chemistry.

To produce better quality, lower cost EH36, Canadian mills would have to develop new steel processing technology or utilize on-line accelerated cooling. Market demand would have to support such an investment and this demand is very uncertain. We note that foreign proponents of on-line accelerated cooling have commenced proceedings to obtain approval of this technology from ship building and classification groups.

The industry recognizes the need for improved quality ship plate and is familiar with new technologies to satisfy this market. However, little work in Canada has been done to respond to this market opportunity. It appears that the Canadian industry is waiting for developments in ship building capacity and acceptance of new technology before considering new commitments to this market.

7.0 GENERAL STRUCTURAL PLATE

Structural plate demand was examined in two product areas:

- 38 ksi - 70 ksi structural plate; and
- 70 ksi and over high strength structural and abrasion resistant plate.

The demand for structural plate, when segmented on the basis of yield strength, is focused in two areas:

- carbon steel structural plate ranging from 38 - 50 ksi yield strength; and
- high stength, low alloy quenched and tempered plate of 100 ksi minimum yield strength.

Demand is not strong for high strength low alloy steel plate of 50 - 70 ksi yield strength although a variety of grades are available with good low temperature toughness and weldability. In comparison, economics of lower strength carbon steel plate are more attractive. If strength is a major design criterion, then economics improve as maximum strength levels are approached. Thus, 50 - 70 ksi plate appears to be at an economic disadvantage in most structural design applications.

The common applications of 38 - 50 ksi yield strength plate are:

- pressure vessels and storage tanks for moderate or low temperature service; and
- general construction of welded structures.

When low temperature toughness is required, these steels are often manufactured to ASTM specification A516. Plates of thickness 1.5 inches and under

can be supplied in the as rolled condition. Plates of thickness greater than 1.5 inches are normalized.

Structural fabricators believe that A516 grades offer good economics and acceptable properties at relatively low temperatures.

Many tanks and pressure vessels are double wall construction. The inner shell is usually constructed of plates with a maximum thickness of up to 1.75 inches. The outer shell of 0.25 inch thick plate acts as a vapour or liquid seal and insulator.

Pressure vessel and tank fabricators seldom use high strength alloy steels, such as ASTM A517, which has a yield strength of 100 ksi. Past construction and economic experience has not been satisfactory. Engineers believe that forming and welding complexities of this steel make it difficult to work with. The cost advantage of using thinner plate is offset by the increased cost of structural stiffeners. Therefore, the economics of higher strength steels for these applications are considered to be poor.

Industry estimates place the demand for 38 - 50 ksi structural plate at up to 90% of the total structural plate demand. The remaining 10% of demand is for 100 ksi HSLA structural and abrasion resistant plate products.

The common uses of 100 ksi quenched and tempered structural and abrasion resistant plate are:

- off-highway equipment manufacturing;
- transportation vehicles such as rail cars and trailers; and
- general high strength construction applications.

The use of high strength plate in equipment and vehicle design reduces weight and operating costs. As such, high strength steels allow designers to optimize the payload to vehicle weight ratio. In such applications, highest possible strength levels, for a given class of material, are desirable.

Abrasion resistant plate, ranging from 320 - 400 BHN, is used when the design criteria are high strength and wear resistance. Typical abrasion resistant plate would have between 6 and 10 times the wear life of mild steel plate.

In the high strength plate market, most applications specify thicknesses in the range of 0.25 - 0.5 inches. Abrasion resistant plate demand is most common in thicknesses to 1.0 inch. In general, 80% of the abrasion resistant plate is supplied at a hardness of approximately 360 BHN.

7.1 User Trends

Users of structural plate are becoming increasingly concerned with low temperature toughness. Toughness specifications have now been established in design codes.

A slow trend exists toward higher strength materials. However, the trend is not new and has existed for the past 20 years. Strength increases of 5 ksi are considered to be significant in this market.

The major concerns of structural plate users are the construction and in-service economics of various structural steels. Pressure vessel and tank fabricators feel that they do not require higher strength materials and cannot justify these steels on construction economics. We perceived a reluctance to utilize higher strength thin plates on grounds of increased material, fabrication and welding costs. These fabricators would prefer to use current strength materials with improved toughness properties.

Users of 100 ksi structural and abrasion resistant plate are able to justify the increased material and fabricating cost on the basis of extended in-service life, reliability and performance. These users pointed out that the material cost premium is small compared to the labour cost of fabrication. Optimization of payload to weight ratios and design life make these steels economical and desirable.

7.2 Market Opportunities

Considering product applications, it is apparent that acceptable strength materials are currently available to users. In most applications, users do not feel there is a need for higher strength material.

A market opportunity exists for more economical 38 - 70 ksi yield strength plate with improved toughness. Users of this plate appear to be more sensitive to materials cost and fabrication economics. Lower cost plate in these grades could be produced if grain refinement was achieved through steel processing rather than through alloy additions such a niobium and vanadium. Annual demand in this market is roughly 1,000,000 tonnes.

The market demand for 70 - 100 ksi structural plate and abrasion resistant plate is approximately 50,000 tonnes per year. It appears that this market is less sensitive to material cost. These users demand high quality plate and uniformity of properties. If steel mills could develop a processing technology that would allow reduced alloying and heat treatment, significant overall cost savings may be realized. Therefore, there appears to be a market opportunity for steel producers to improve the profitability of such plate sales through the development of a processing technology resulting in cheaper, high strength and abrasion resistant plate.

7.3 View of Canadian Steel Producers

Producers are very interested in steel processing technology that would reduce the cost of 38 - 70 ksi structural steel grades. Since this market represents roughly 90% of total structural plate demand, small savings on large tonnage of product could significantly improve profitability. The industry sees technology development for this product market to be justified and warranted by the market demand and economic impact of such cost reductions.

With respect to the high strength 70 - 100 ksi structural and abrasion resistant plate market, steel producers are reluctant to consider alternative technology to quenched and tempered alloy steels. The market demand is small

and end user marketing is necessary. Demand growth is limited to growth in current applications. Additionally, users are quality oriented. Traditional quenched and tempered heat treatment represents quality processing to these users. It is felt that users would be reluctant to specify alternative heat treatment steels when traditional materials have achieved desired levels of reliability and performance. To influence selection to new products, a significant marketing investment and effort would be necessary to "sell" new technology products to users. Producers indicated that this small market did not offer significant potential to justify investment in the capital and marketing effort.

8.0 SUMMARY OF MARKET OPPORTUNITIES

8.1 Line Pipe

The trend toward higher strength line pipe is expected to be slow. New higher strength pipe is likely to appear in small strength increments. Based on past trends and assuming a 3 to 5 year development cycle, the market for grade 100 grade line pipe may not appear for 20 years.

We note however, that one user group has advanced the case for grade 100 in the near future. This group argues that the economic savings of grade 100 justify development time and cost. The group believes that the cumbersome process of developing and testing intermediate grades such as 80, offers less economic advantage, may not be necessary and could be avoided. However, no user or supplier group has shown a willingness to undertake the development of grade 100 at this time.

Given the conservative approach by users, future line pipe demand is likely to be for more economical, better quality, low temperature line pipe in current and moderately higher strength grades (e.g. grade 80).

8.2 Plate for Ships and Offshore Structures

A trend toward higher strength ship plate is not evident at this time. Vessels for Arctic service are expected to be fabricated from thick plate of roughly 50 ksi yield strength. The user need is for existing strength and tougher plate at lower design temperatures. To maintain toughness and lower the transition temperature, increased limits on Ni and Mo have been allowed for grade EH36 ship plate.

With respect to floating offshore structures, a market may develop for higher strength plate as field development of these structures progresses. It is necessary to minimize the weight of floating structures. Thus, higher

strength thin plate is desirable. However, very conservative design practice is expected until sufficient experience has been accrued to advance design criteria in this direction.

Caisson or gravity cone offshore structures are expected to be fabricated from lower temperature fracture resistant ship plate steels. However, concrete could be substituted for steel. Concrete properties and cost make it a competitive alternative to steel in these applications.

8.3 General Structural Plate

8.3.1 38 - 70 ksi Structural Plate

For users of this plate, there is no evident trend toward higher strength steels. Fabricators of tanks and pressure vessels claim construction economics and experience with higher strength materials have been unsatisfactory. In these applications, existing strength properties are considered to be adequate.

Users of this plate are sensitive to material costs and conservative in their approach to new materials. As such, lower cost existing plate grades would provide a strong competitive advantage in this market.

Toughness properties and specifications are becoming more significant to traditional users of structural plate. This trend is expected to continue.

8.3.2 70 - 100 ksi Structural and Abrasion Resistant Plate

Traditional users of high strength structural and abrasion resistant plate have been concerned with uniformity of properties, weldability and service life. Users are prepared to pay a premium price for superior properties and performance.

This is not a large plate market. Suppliers characterized demand as stable with growth limited by growth of existing applications. End user marketing is necessary in this plate market.

There does not appear to be a major trend to increased strength. However, trends to improved quality and uniformity are evident and expected to continue.

It appears that the cost of these steels make them uneconomical in applications other than extreme service conditions or where weight savings are desirable. More economical steels with equivalent properties could cause expansion of this segment of the plate market.

8.4 Resource Project Steel Demand Constraints

In the preceeding sections of this report, we have identified high tonnages of plate demand related to Arctic and frontier resource development. These estimates are based on the established or proposed plans of various projects.

While we have identified particular product and application constraints, further constraints on the projects themselves must be examined.

On the steel "supply side", the proposed project schedules and requirements could exceed Canadian steel mill and ship building capabilities. The issues and expected constraints on Canadian supply are summarized as follows:

- Canadian steel mills may not have sufficient capacity to meet demand or adequate capability to produce the necessary plate properties;

- sufficient ship building capacity and capability may not exist if rapid development occurs;

- Canadian steel mills and ship builders are not committed to any planned action to overcome these deficiencies; and

- intense competition is expected from foreign steel producers and ship builders.

Similarly, significant "demand side" constraints also exist for these projects. The following constraints on resource project schedules will impact on steel requirements and timing:

- Arctic and offshore reserve potential is unknown at this time. As such, current forecasts are only based on expectations, not proven recoverable reserves;

- conservative regulatory groups that could slow the rate of development;

- Canadian government policies may affect project economics;

- uncertain escalation in the price of imported oil;

- slower growth rate in Canadian demand for natural gas;

- uncertain rate of technical development and demonstration of field construction and operating systems; and

- a lack of a commitment to a specific transportation system at this time (i.e. pipe line system versus marine system).

In summary, both supply and demand side resource project constraints make it impossible to predict the extent and timing of related steel demand. Therefore, we have not attempted to prepare a yearly annual forecast of incremental steel requirements based on project schedules.

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Exhibit 5

POTENTIAL FUTURE DIRECTOR OF CANADIAN PLATE CONSUMPTION (METRIC TONNES)

	UNDER 50 KSI	50 – 70 KSI	OVER 70 KSI	TOTAL
ANNUAL CONSUMPTION OF PLATE ≤1.5"	935,000	575,000	50,000	1,560,000
RESOURCE PROJECT DEMAND 1983 – 1995				
LINE PIPE PLATE ≤1.5"	–	987,000	3,370,000[1]	4,357,000
SHIP PLATE ≤1.5"	990,000	1,840,000	–	2,830,000
TOTAL PROJECT DEMAND FOR PLATE ≤1.5"	990,000	2,827,000	3,370,000	7,187,000[2]

NOTES: (1) GRADE-70 OR HIGHER STRENGTH LINE PIPE.

(2) FIGURES INCLUDE COMPETING TRANSPORTATION SYSTEMS AS ARCTIC OIL AND GAS PIPE LINES COMPETE WITH ARCTIC CRUDE OIL AND LNG CARRIERS. THEREFORE, SOME DOUBLE COUNTING EXISTS IN THE TOTAL FIGURES.

8.5 Future Direction of Canadian Plate Consumption

We believe that there will be a continuing trend towards higher yield strength, low carbon, low alloy steels. As shown in Exhibit 5, resource project steel plate requirements will be focused in the 50 - 70 ksi and over 70 ksi yield strength ranges.

Assuming frontier resource development does not fall greatly behind proposed schedules, related steel demand could exceed 3,000,000 tonnes by 1995. On this basis, strong demand should exist for economical, higher strength line pipe and ship plate with improved low temperature fracture toughness.

9.0 DEVELOPMENTS IN STEEL PROCESSING TECHNOLOGY

Throughout the 70's, the world-wide steel industry and its suppliers have been investigating and developing new steel processing techniques. The industry research has been focused on developing new technology that would improve strength, toughness, weldability and production economics of HSLA steels.

A significant amount of research has been devoted to steel technology that:

- maximizes strength and toughness properties by refining ferrite grain size;
- minimizes the requirements for additional grain refinement alloys;
- increases rolling mill productivity; and
- minimizes subsequent heat treatment requirements.

As a result, a "transformation strengthening" technology has been developed that uses the following two processing methods:

- on-line accelerated cooling (OLAC); and
- on-line direct quenching.

Both processes incorporate an on-line water quenching system near the exit end of the rolling mill. Plate is water cooled as soon as possible after the final rolling pass.

A significant difference between the processes lies in cooling rates and cooling finish temperatures. The OLAC process quenches plates at rates up to 15°C per second to a finish temperature of approximately 550°C. At this temperature, self-tempering is achieved by air-cooling the plate to room temperature. The direct quenching process utilizes a roller quench to cool plates

directly to room temperature at rates of 50°C to 70°C per second. A roller quench is used to achieve such high rates of cooling and to ensure plate flatness.

While both processes are physically and operationally different, they achieve somewhat similar results. Direct quenching is essentially accelerated cooling to room temperature using higher quench rates. The concept of "transformation strengthening" is used in both processes to different extents.

These processes are competititive for producing higher strength, tough, weldable and lower cost plate. We compared each technique and its capability to provide improved plate steel grades and new plate products.

9.1 On-line Accelerated Cooling

The OLAC process has been commercially demonstrated and has been used to produce up to 70 ksi skelp and structural plate at lower cost. Toughness properties have generally been maintained and weldability has improved. The process has been tested with plates up to 1.5 inches in thickness. Very flat plate with uniformity in through thickness, length and width directions has been produced. Further heat treatment is not necessary.

OLAC cost savings may result from:

- reduction of grain refining alloys;
- increased rolling mill productivity; and
- decreased production costs since further heat treating is not necessary.

The process is fully in line with the rolling mill. Cooling is performed by laminar flow on the top and spray on the bottom.

The key to the process appears to be an extensive computer based control system which determines and sets production variables to achieve the desired properties.

The control system determines and controls:

- slab reheating temperature;
- finish-rolling temperature;
- cooling rate, water pressure and volume; and
- OLAC finish temperature.

In essence, the OLAC system was created by developing an extensive control system and mill process that could optimize the transformation strengthening capabilities of a conventional laminar and spray cooling system. As many producers already have such an on-line cooling system installed, the OLAC process control could reasonably be applied. The OLAC process would not require extensive alterations to a steel mill lay-out. Therefore, the capital investment for OLAC processing would not be prohibitive.

The disadvantages to OLAC appear to be a limited capability to increase strength and toughness properties greatly beyond that obtained by controlled rolling. The limits of OLAC are estimated at 80 - 85 ksi yield strength. OLAC does not sacrifice or improve toughness significantly. The OLAC process may not be capable of producing substitute, high strength, low alloy structural or abrasion resistant plate. Similarly, it may not be capable of producing grade 100 line pipe steel with the required toughness properties at this time.

The capabilities and advantages of OLAC appear in the substitute product markets. The OLAC process can be used to produce lower cost, improved quality existing and moderately higher strength grades of general structural and line pipe plate steels.

9.2 Direct Quench

Direct quenching technology has been demonstrated with good strength and toughness results in plates up to 2.0 inches thick.

The roller quench allows this process to attain the highest practical cooling rates. Thus, direct quenching maximizes the strength/toughness benefits of transformation strengthening. Additionally, the roller quench produces good plate flatness in the as-quenched condition.

Direct quenching appears to offer more capability than OLAC in terms of yield strength and plate thickness limits. With direct quenching, it would be possible to produce very thick 100 ksi line pipe or structural and abrasion resistant plate with good toughness and improved weldability. Additionally, cost savings are claimed from:

- reduction of grain refinement alloys;
- increased rolling mill productivity; and
- decreased heat treatment energy requirements.

The disadvantage of direct quenching is the cost of installing the process. An in-line roller quench unit is necessary and many mill layouts do not offer sufficient flexibility to economically locate this unit.

From a market standpoint, direct quench offers capabilities for producers to satisfy both substitute and new product markets. This process could allow production of lower cost, improved grades of line pipe, and low alloy structural plate in the range of 38 - 100 ksi yield strength. The high cooling rates of this process allow these steels to be produced in thicknesses up to 2.0". By contrast, OLAC capabilities are limited to thicknesses of up to 1.5 inches.

9.3 View of Producers

Canadian steel producers are actively investigating OLAC processing as a technique for improving steel quality, reducing alloy requirements and heat treatment costs. An OLAC system could be adapted to several Canadian plate mills.

Producers do not view OLAC as a system for producing new high strength products. These mills feel OLAC is justified on the basis of alloy cost savings achievable in large tonnage plate markets, such as 38 - 70 ksi structural plate.

Canadian mills are not interested in direct quenching at this time. The industry envisions production flow difficulties with an on-line roller quench. Furthermore, some Canadian plate mill layouts would prohibit economic installation of the roller quench unit. Finally, Canadian producers do not see a significant market at this time for the extended thick plate and strength capabilities of the direct quench system. Producers believe that OLAC capabilities are consistent and sufficient to service a very large percentage of the high strength skelp and plate market demand.

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TORONTO, June 1982